Evolutionary Programming for Estimating Nitrate Concentration in Water

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Abstract: The study of contamination levels in wastewater is very important for health, economic and legal reasons. European Directive 2000/60/CE establishes the quality levels for groundwater. It also binds control between other nitrate concentration. In this work, we show a method based on evolutionary programming for estimating nitrate concentration in a sample of wastewater treated by a non conventional system such as land application.

Key-Words: - Nitrate, Evolutionary Programming, Land Application, Wastewater.

1 Introduction

The performance of a Land Application system for urban wastewater treating is based on the adequate application of waste water flows to a land with vegetation and trees [9]. Part of the flow evapotranspires and the rest of it is filtered by the soil, reaching the saturated zone. The purification is done jointly by soil, micro organism and plants by means of physical, chemical and biological mechanisms. This way allows the removal of suspended solids, organic matter, nitrogen, phosphorus and so on. The amount of waste water applied to land is usually greater than vegetation requirements and soil reserve. therefore, the water excess contributes (by infiltration) to underlying aquifer recharge, which is a resource appreciation when the quality of the water to infiltrate is good enough [8]. The Directive 91/271/CEE regulates collecting, treatment and flowing [6] of wastewater and Directive 91/676/CEE [5] tries to reduce the contamination caused by nitrates from agriculture and to prevent new contaminating sources by establishing a limited value of 50 mg/l [7]. The excess of nitrate contamination in water may cause disease in children.

This work presents the study of nitrate concentration in the infiltrated flow of a Land Application System. We use a Classic Evolutionary Programming (CEP) algorithm for the optimization of the adjusting values. The function represents the transmittance variation of a sample with a known nitrate concentration (patterns). This process allows an estimation of the nitrate concentration of a sample of treated wastewater.

The rest of the paper is organized as follows. Section 2 describes the materials and methods used to estimate the nitrate concentration. In section 3 we explain the evolutionary programming algorithm and its application to the problem. The results are described in section 4 and the paper finishes with the main conclusions of the work.

2 The problem of nitrate concentration estimation and analysis

2.1 Hardware system

We have used for this work an EPP2000 Stellarnet spectrometer that allows an analysis of the light amplitude from 200 to 800 nm wavelength and a combined light source of deuterium and halogen within this range. Water samples have been placed in a 10 mm quartz tray. Light is guided by a 400 µm optical fibber optimized for ultraviolet transmission. We have measured the spectral response from 200 to 800 nm in 0,5 nm steps. Fig. 1 shows the spectrometer, light source and tray withstanding.

Fig. 1. Hardware System.

2.1 Spectral response of nitrate contamination

Nitrate salts dissolved in water show a selective wavelength response. The highest absorption is reached in the ultraviolet range (210-230 nm). The value of absorbed light power is related to nitrate concentration.

Fig. 2 shows the transmittance variation in a sample of pure water with different nitrate concentration from 200 to 800 nm (pattern). The main variations are in 200 to 300 nm. As seen in Fig. 2, there is a shift in the maximum absorption wavelength related to nitrate concentration. The transmittance values for this patterns are in the range of 10-100%.

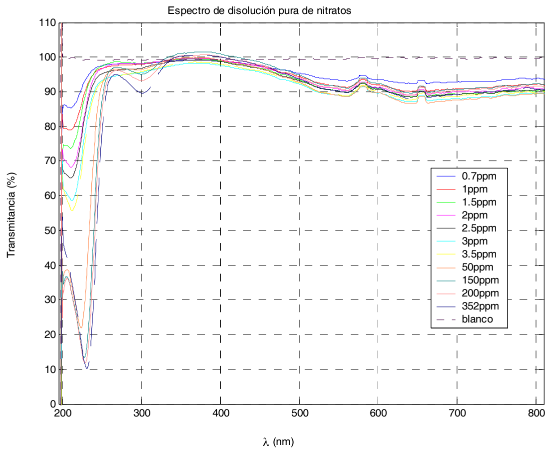

Fig. 2 Transmittance for different samples of pure water with several nitrate concentrations in 200-800 nm range.

Fig. 3 shows the transmittance variation of a real sample of treated wastewater taken from the Land Application of Redueña (Madrid, Spain). There is a maximum of absorption due to nitrate around 220 nm and also a high reduction in transmittance range, with values from 20 to 70 %.

This reduction is due to the rest of the pollutants of the treated wastewater, which maximums values of absorption are out of the range of this figure. However they contribute to reduce the transmittance of the sample in the range of nitrate response (interference). For this reason, it is not suitable to take an estimation of nitrate concentration from one value of transmittance in a particular wavelength value.

In this work, we present a solution based on the study of the spectral response of a treated wastewater sample, taken from a Land Application by comparing the spectral responses of several samples of pure water with a known nitrate concentration (patterns).

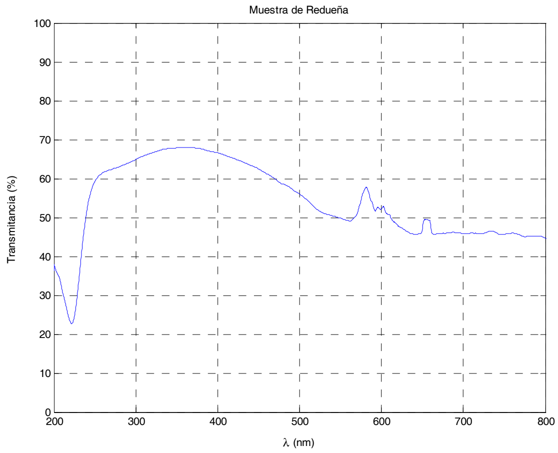

Fig. 3. Transmittance of a sample of treated wastewater from Redueña within a 200 to 800 nm range.

3 Algorithm description and programming

2.1 Evolutionary Programming Algorithm

According to Fogel [2], [3] and Bäck y Schwefel [10], the algorithm of Classic Evolutionary Programming (CEP) with self adaptive mutation may be described as follows:

1. Generate an initial population of μ individuals and set the number of generations k =1. Each individual is taken as a pair of real valued vectors (x_i, η_i), $\forall i \in \{1,...,\mu\}$, where x_i's are objective variables and η_i's are standard deviations for Gaussian mutations.
2. Evaluate the fitness score for each individual (x_i, η_i), $\forall i \in \{1,...,\mu\}$, of the population based on de objective function $f(x_i)$.
3. Each parent (x_i, η_i), $i = 1..\mu$, creates a single offspring (x_i', η_i') by: for $j = 1,..,n$

$$x_i'(j) = x_i(j) + \eta_i(j) N_j(0,1) \quad (1)$$

$$\eta_i'(j) = \eta_i(j) \exp\left(\tau' N(0,1) + \tau N_j(0,1)\right) \quad (2)$$

Where N(0,1) denotes a normally distributed one-dimensional random number with mean zero and standard deviation one. The factors τ and τ' are $\left(\sqrt{2\sqrt{n}}\right)^{-1}$ and $\left(\sqrt{2n}\right)^{-1}$ respectively and n is the number of variables to optimize[1], [10].

4. Calculate the fitness of each offspring $(x_i', \eta_i'), \forall i \in \{1..\mu\}$.
5. Conduct pairwise comparison over the union of parents (x_i, η_i) and offspring (x_i', η_i') $\forall i \in \{1,..,\mu\}$. For each individual, q opponents are chosen uniformly at random from all parents and offspring. For each comparison, if the individual's fitness is no smaller than the opponent's, it receives a "win".
6. Select the μ individuals out of (x_i, η_i) and (x_i', η_i'), $\forall i \in \{1,..,\mu\}$, that have the most wins to be parents of the next generation.
7. Stop if the halting criterion is satisfied; otherwise, k= k+1 and go to step 3.

3.1 Application to nitrate concentration estimation

The above mentioned algorithm may be used for nitrate concentration estimation in treated wastewater. The process is stated below.

The interference due to other pollutants does not allow an exact selection of the most adequate pattern to the sample due to the variations in the range of the transmittance as mentioned above. The shift of the maximum absorption wavelength with nitrate concentration allows a distinction between different values. However it is not precise enough for estimating when other pollutants apart from nitrate are present.

In order to choose the most adequate pattern, they must be adapted to minimize the mean square error of their difference with the sample to estimate.

Let m(λ) be the spectral response of the transmittance of the sample to estimate. Let a and b real values in the range [0, 1] and $p_i(\lambda)$ the spectral transmittance response for each pattern. We will try to adequate each pattern as shown in equation (3).

$$x_i(\lambda) = a_i + b_i \, p_i(\lambda) \quad (3)$$

For each pattern, we find the values a_i and b_i to minimize the mean square error as shows the following equation:

$$f(a_i, b_i) = \sum_{\lambda=200}^{300} \left(m(\lambda) - \left(a_i + b_i p_i(\lambda) \right) \right)^2 \quad (4)$$

The optimum values for a_i and b_i are obtained with the algorithm shown in section 2.1. The initial values for a_i and b_i are chosen at random. We form an initial population of 50 pairs (parents) this way for each pattern.

Each parent creates an offspring following a normally distribution with the same mean as the parent and standard deviation as given in equation (2), with $\tau' = \left(\sqrt{2\sqrt{2}}\right)^{-1}$ and $\tau = \left(\sqrt{4}\right)^{-1}$ [11]. The process follows for 100 generations.

When the process has finished, the best pair of (ai, bi) for each pattern is found. The nitrate concentration of the sample is the one of the most adjusted pattern, since it is the one that minimizes the equation (4).

4 Results

In order to prove the method stated above, we have taken a sample of treated wastewater from Redueña's Land Application. We know that its nitrate concentration is 11 ppm. We have a set of paterns from 2 ppm to 50 ppm in 2 ppm interval and from 55 ppm to 100 ppm in 5 ppm interval.

When the process has been completed, we have obtained Figures 4 and 5. They show the evolution of a_i and b_i along 100 generations.

This evolution is quite fast, reaching the definitive values around the tenth generation. The last obtained values were a = 0.0501941 and b = 1.

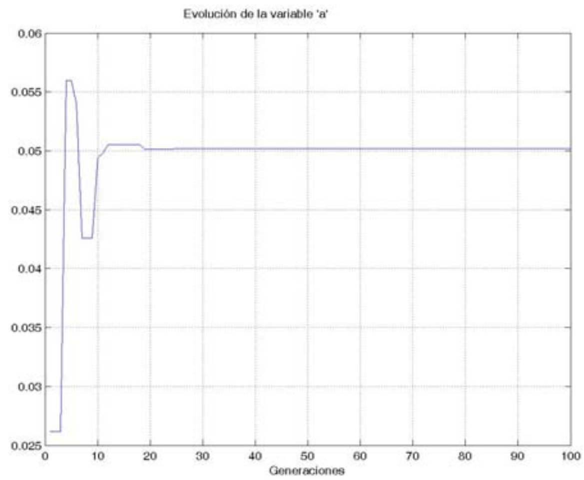

Fig. 4. Evolution of variable "a".

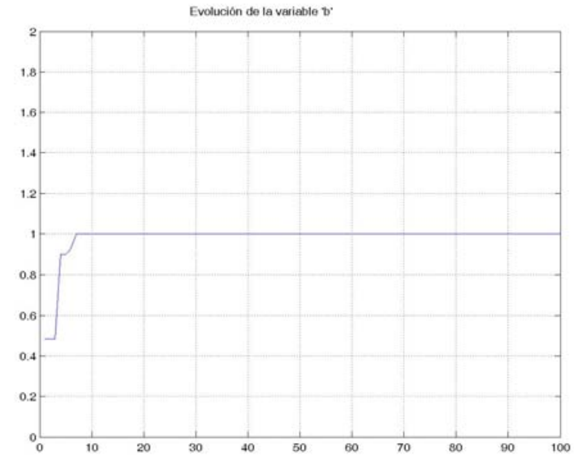

Fig. 5. Evolution of variable "b".

By using these values to adapt the best pattern (14 ppm) we obtain figure 6. this figure shows the transmittance of the sample (solid line) and the pattern adapted with the pair of variables given by the algorithm (dashed line). As is shown in figure 6, both variations are very similar. The difference between them is due to the variability of the available patterns.

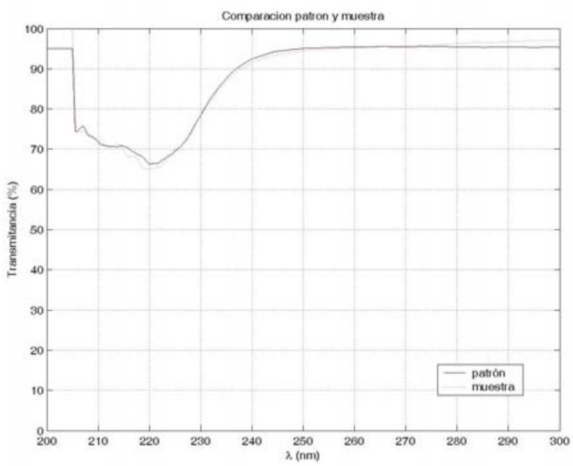

Fig. 6. Comparison between 14 ppm adapted pattern and treated wastewater simple.

5 Conclusion

In this work we have described a method for estimating the nitrate concentration of a sample of treated wastewater by using a classic evolutionary algorithm.

We have checked the method with a sample taken from a Land Application System. The accuracy of this method depends on the pattern quality.

Acknowledgement

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